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VOLTAGE DIVIDERS
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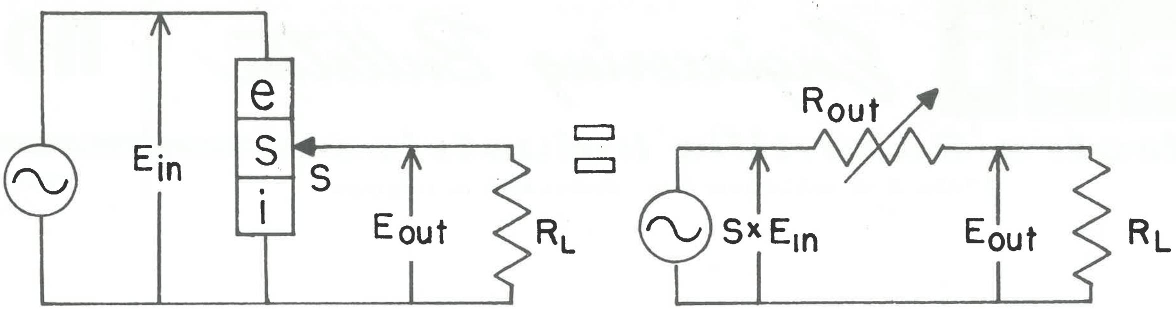
THE EFFECTS OF OUTPUT LOADING ON RESISTIVE VOLTAGE DIVIDERS

When a load resistor is placed across the output of a DEKAPOT or DEKAVIDER the output voltage will change. It may or may not change enough to be serious; this will depend on the accuracy needed. The manufacturing tolerance (specified linearity) may be greater than the effect of a high resistance load. If this is the case, the change in output can be neglected.

To determine the output loading effect we need to know something of the user's accuracy requirement and we need to know the load resistance. Then we can calculate how these affect the divider circuit. A resistive divider can be represented by an equivalent generator and output resistor in series. With this equivalent circuit and a known load resistance, the effect on output voltage can be easily analyzed. Variations in output voltage can be expressed in LINEARITY DEVIATION, the deviation from nominal output relative to the input, or in OUTPUT DEVIATION, the deviation from nominal output relative to the output.

This bulletin contains equivalent circuit values for specific ESI DEKAPOTS and DEKAVIDERS, and a nomogram for obtaining the linearity deviation and output deviation for any expected value of output loading. There is also some extension of the discussion of the equivalent circuit and of loading problems. Finally, a circuit is included with which accurate results can be obtained even with a heavily loaded output circuit.

Litho in U.S.A.



EQUIVALENT CIRCUIT

EQUIVALENT CIRCUIT OF A RESISTIVE VOLTAGE DIVIDER

A voltage divider can be accurately represented by an equivalent circuit containing only two elements:

1. A RESISTOR, which equals the output resistance of the divider. This varies with dial setting.
2. An equivalent GENERATOR, with open circuit voltage equal to the divider setting times the input voltage--that is, (S x E_{in}).

Figure 1 is a plot of the output resistance of a Kelvin-Varley resistive divider, as a function of dial setting. The resistance values are symmetrical about a setting of 0.5. For example the output resistance at a setting of 0.985 will be the same as that for a setting of 0.015. The resistance corresponding to 0.015 can be easily found on figure 1.

TO MEASURE THE OUTPUT RESISTANCE at any setting, short the input terminals together and measure the resistance across the output terminals.

For a Kelvin-Varley circuit the maximum output resistance will occur at settings of 0.455... and 0.544...

EFFECT OF OUTPUT LOADING

Figure 2 is a nomogram for determining the linearity deviation and output deviation when the load resistance, output resistance, and setting are known.

The output loading effects can be determined from the equivalent circuit. These effects are usually expressed in terms of either linearity deviation or output deviation.

LINEARITY DEVIATION

Definition: using the notation in the figure on page 2

$$\text{LINEARITY DEVIATION} \equiv \frac{E_{out} - SE_{in}}{E_{in}}$$

To obtain the output voltage from the setting and linearity deviation:

$$E_{out} = E_{in} (S + \text{Linearity Deviation})$$

The effect of output loading in terms of the equivalent circuit:

First noting that the output voltage is:

$$E_{out} = \frac{SE_{in} R_L}{R_{out} + R_L}$$

The linearity deviation can be expressed as:

$$\text{LINEARITY DEVIATION} = \frac{-S}{1 + \frac{R_L}{R_{out}}}$$

For a Kelvin-Varley circuit maximum linearity deviation will occur at a setting of 0.655•••

OUTPUT DEVIATION

Definition: using the notation in the figure on page 2

$$\text{OUTPUT DEVIATION} \equiv \frac{E_{out} - SE_{in}}{SE_{in}}$$

To obtain output voltage from the setting and output deviation

$$E_{out} = SE_{in} (1 + \text{Output Deviation})$$

The effect of output loading in terms of the equivalent circuit:

The output deviation can be expressed as:

$$\text{OUTPUT DEVIATION} = \frac{-1}{1 + \frac{R_L}{R_{out}}}$$

For a Kelvin-Varley circuit maximum output deviation will occur at settings of 0.455••• and 0.544•••

HOW MUCH LOADING CAN BE NEGLECTED

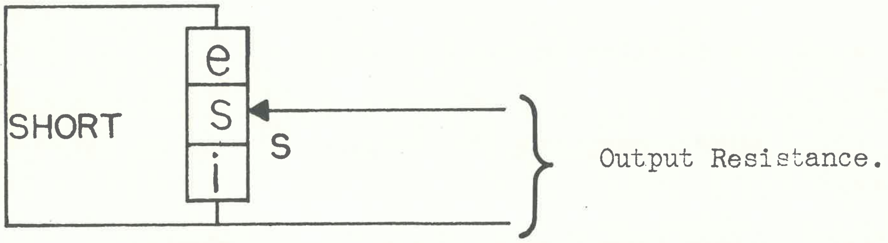
Output loading can be neglected if it does not cause more output shift than the tolerance of the experiment. It can always be neglected if its effect is less than the tolerance of the divider, that is, if the linearity deviation due to output loading is less than the specified divider linearity. Actually the dividers are much better than the specified linearity, especially at low settings. Typical values are compared with specification values on Figures 3 and 4. Figure 3 compares linearity deviation and Figure 4 compares output deviation. The generous safety factor allows for possible resistor stability variations. With this reservation, the divider can be trusted to the typical values. If this is done the output loading deviation should be less than the typical deviation due to resistance tolerance if it is to be neglected.

For checking to see if the loading can be neglected the resistance values from Figure 1 are satisfactory. If the actual loading effect is needed, the output resistance should be measured at the desired setting and this measured value should be used in the calculation.

WHAT IF THE LOADING CHANGES THE OUTPUT TOO MUCH?

There are two possibilities. The loading effect can be calculated and used to correct the data; or, an auxiliary divider can be connected in parallel with the accurate divider, and used to supply the load current.

For calculating the loading correction, use measured values of output resistance and load resistance. To measure output resistance at any setting, short the input terminals of the divider and measure the resistance between the output terminals:



CIRCUIT FOR MEASURING OUTPUT RESISTANCE

Then

$$E_{out} = \frac{SE_{in}}{1 + \frac{R_{out}}{R_L}}$$

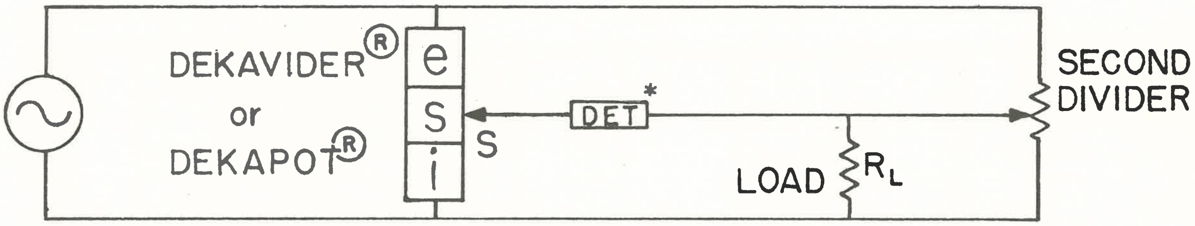
or

$$\text{Linearity Deviation} = \frac{-S}{1 + \frac{R_L}{R_{out}}}$$

and

$$\text{Output Deviation} = \frac{-1}{1 + \frac{R_L}{R_{out}}}$$

The auxiliary divider does not need to be calibrated, but it should have good resolution. Connect the circuit as shown:



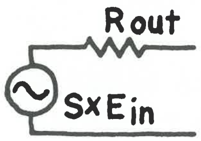
AUXILIARY DIVIDER CONNECTION

TO APPLY A KNOWN VOLTAGE TO THE LOAD

1. Set up the desired value on the DEKAPOT or DEKAVIDER .
2. Adjust the setting of the second divider until the detector indicates a null. When the detector reads zero:
   a. No current is drawn from the DEKAPOT or DEKAVIDER , so there is no loading effect. The load current is supplied by the second divider.

   b. The load voltage is exactly equal to the DEKAPOT or DEKAVIDER output voltage.

*The null detector must be able to detect a change of one dial division on the last dial of the DEKAPOT or DEKAVIDER



EQUIVALENT CIRCUIT

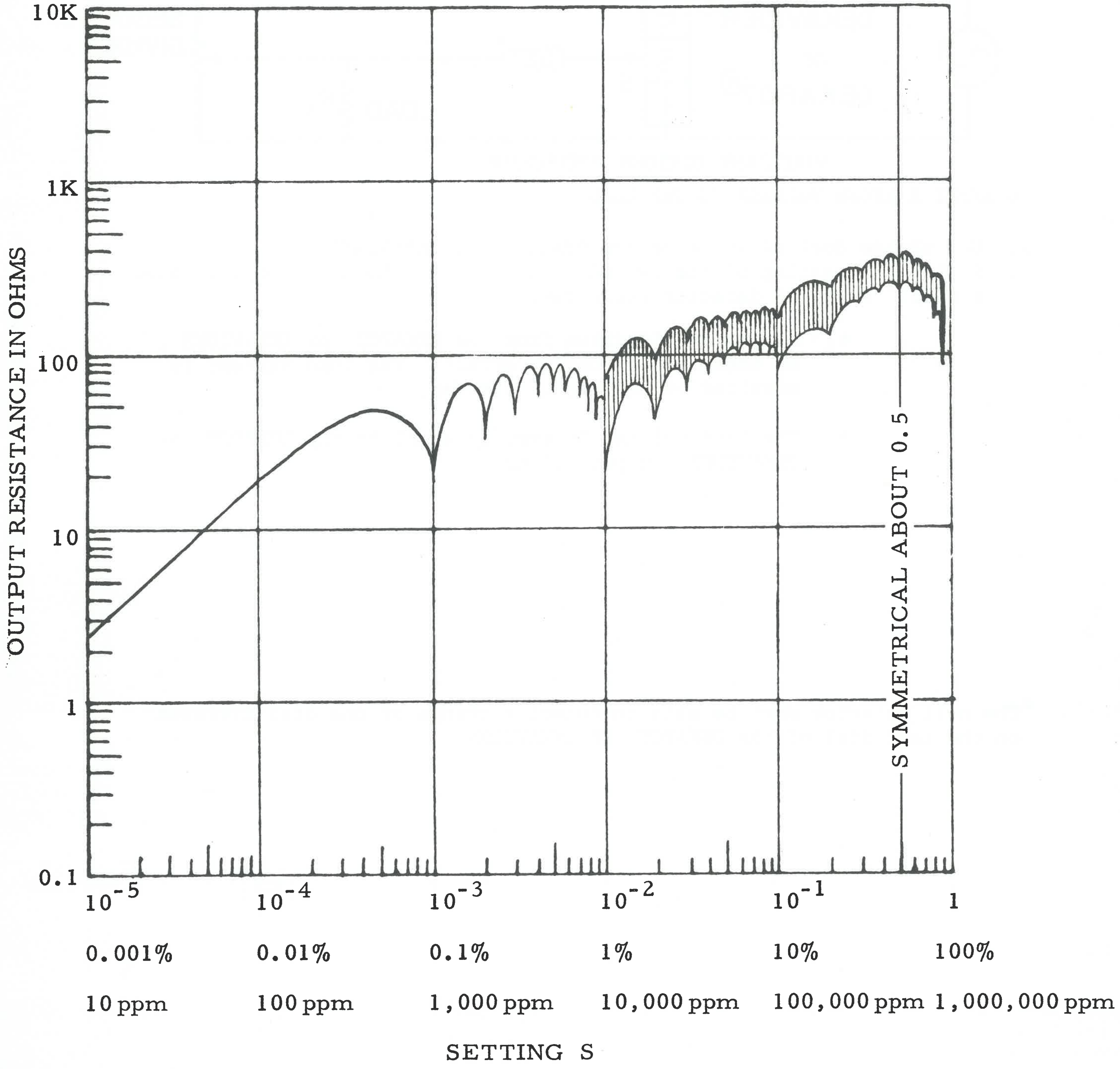
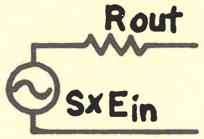


Figure 1a for 1,000 ohm DP-311, DP-411, DV-311 and DV-411



EQUIVALENT CIRCUIT

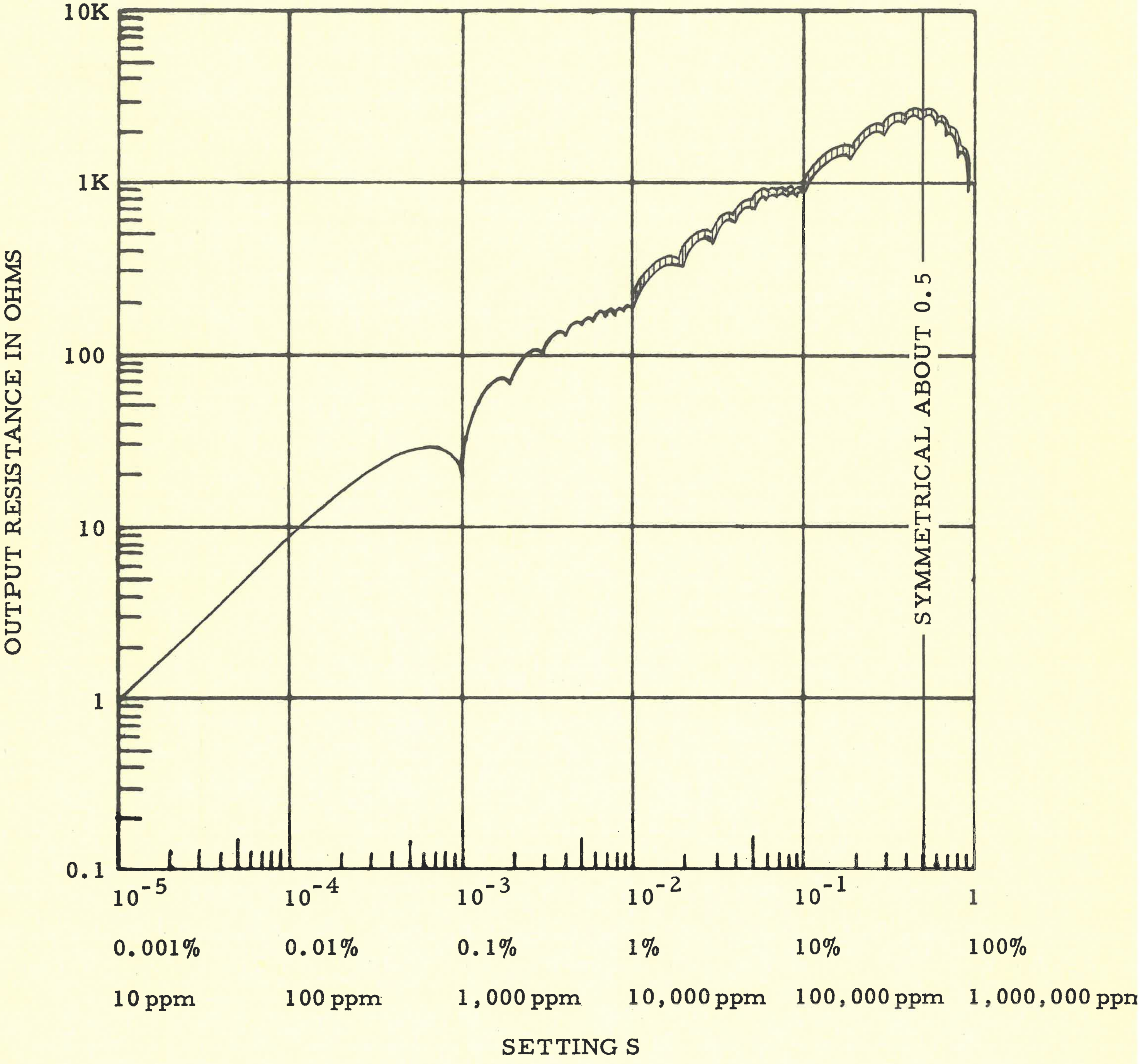
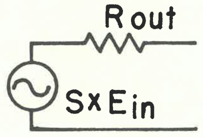


Figure 1b for 10,000 ohm DP-311, DP-411, DV-311 and DV-411



EQUIVALENT CIRCUIT

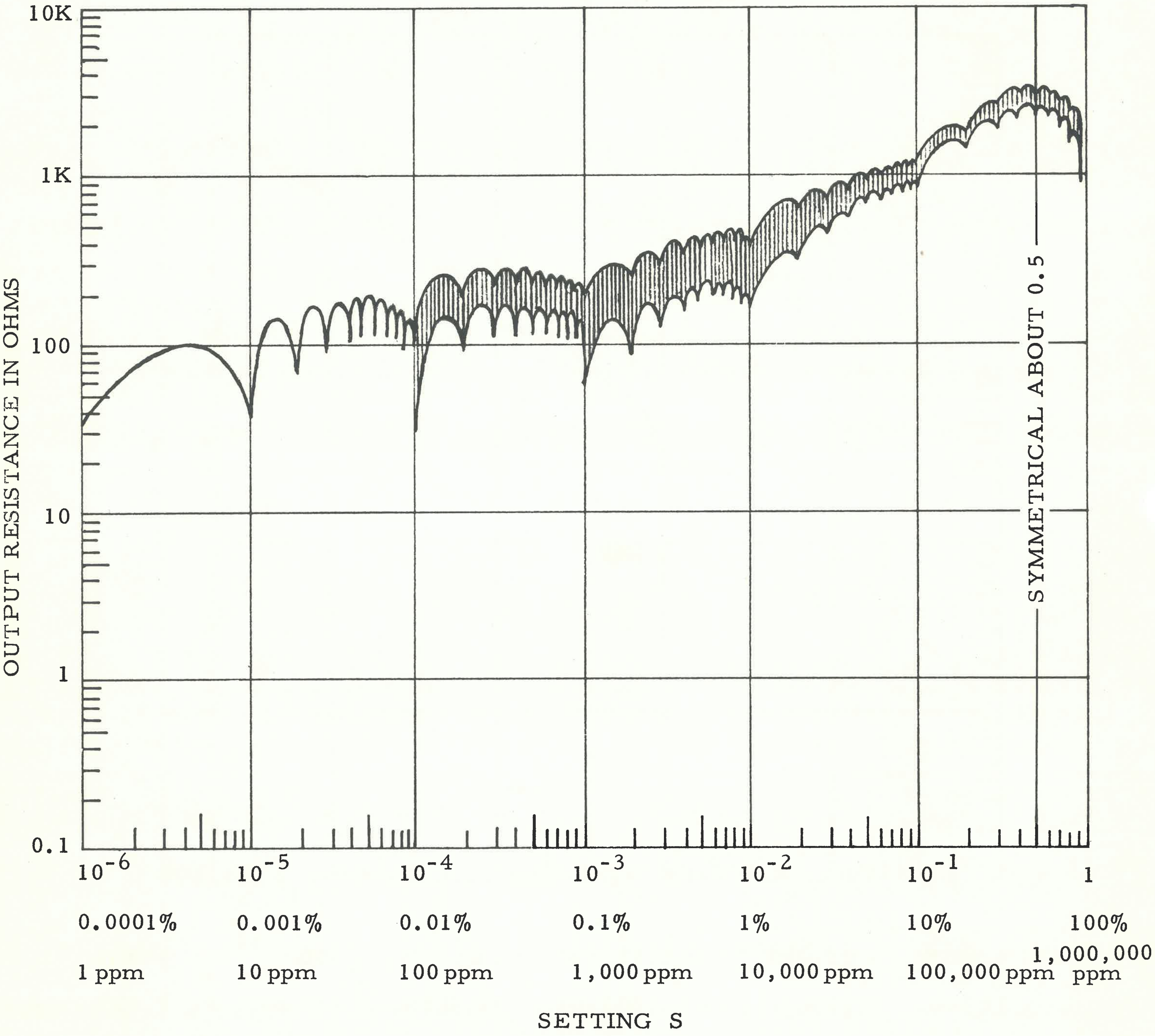


Figure 1c for 10,000 ohm RV-622 and 5,000/10,000 ohm RV-632

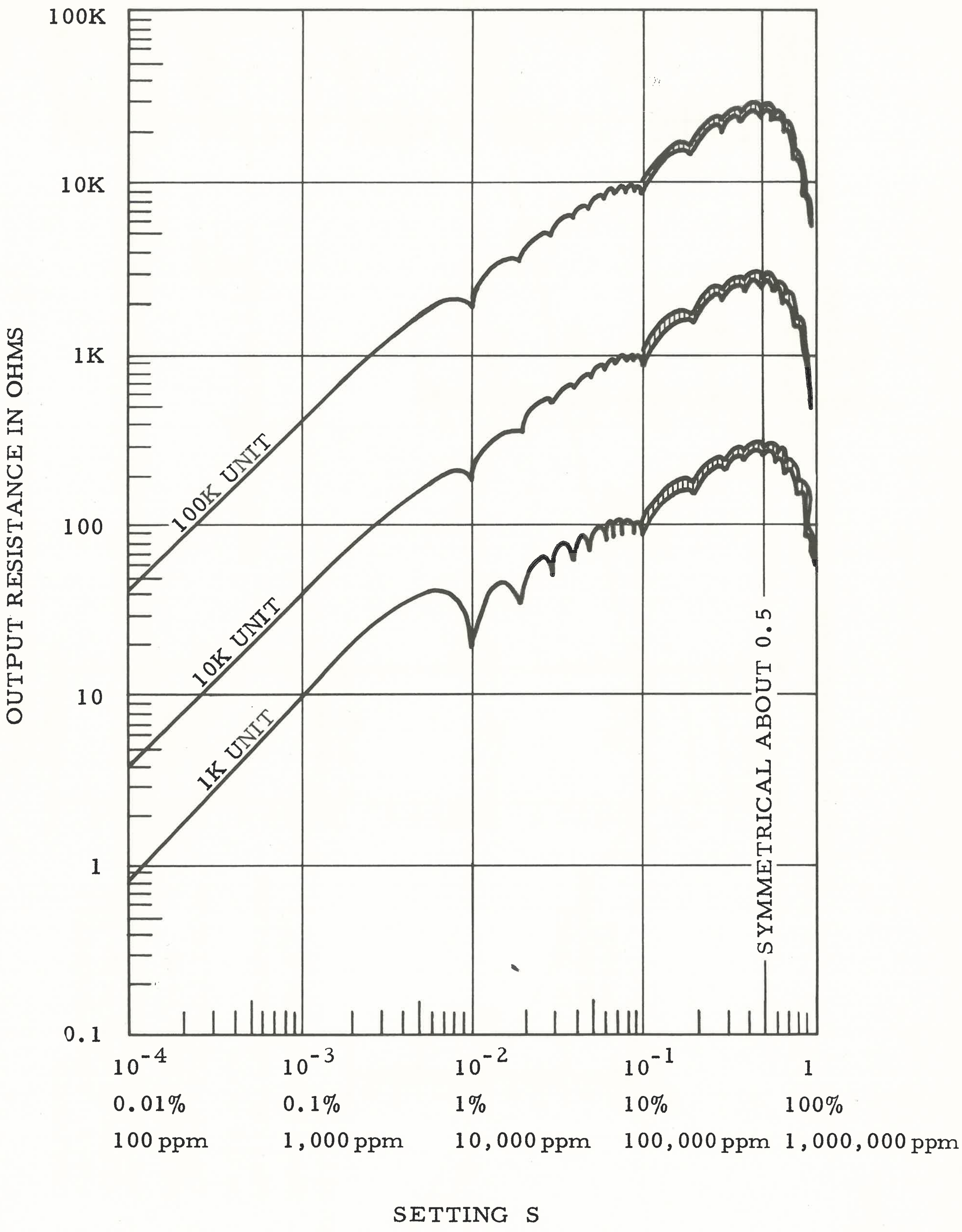
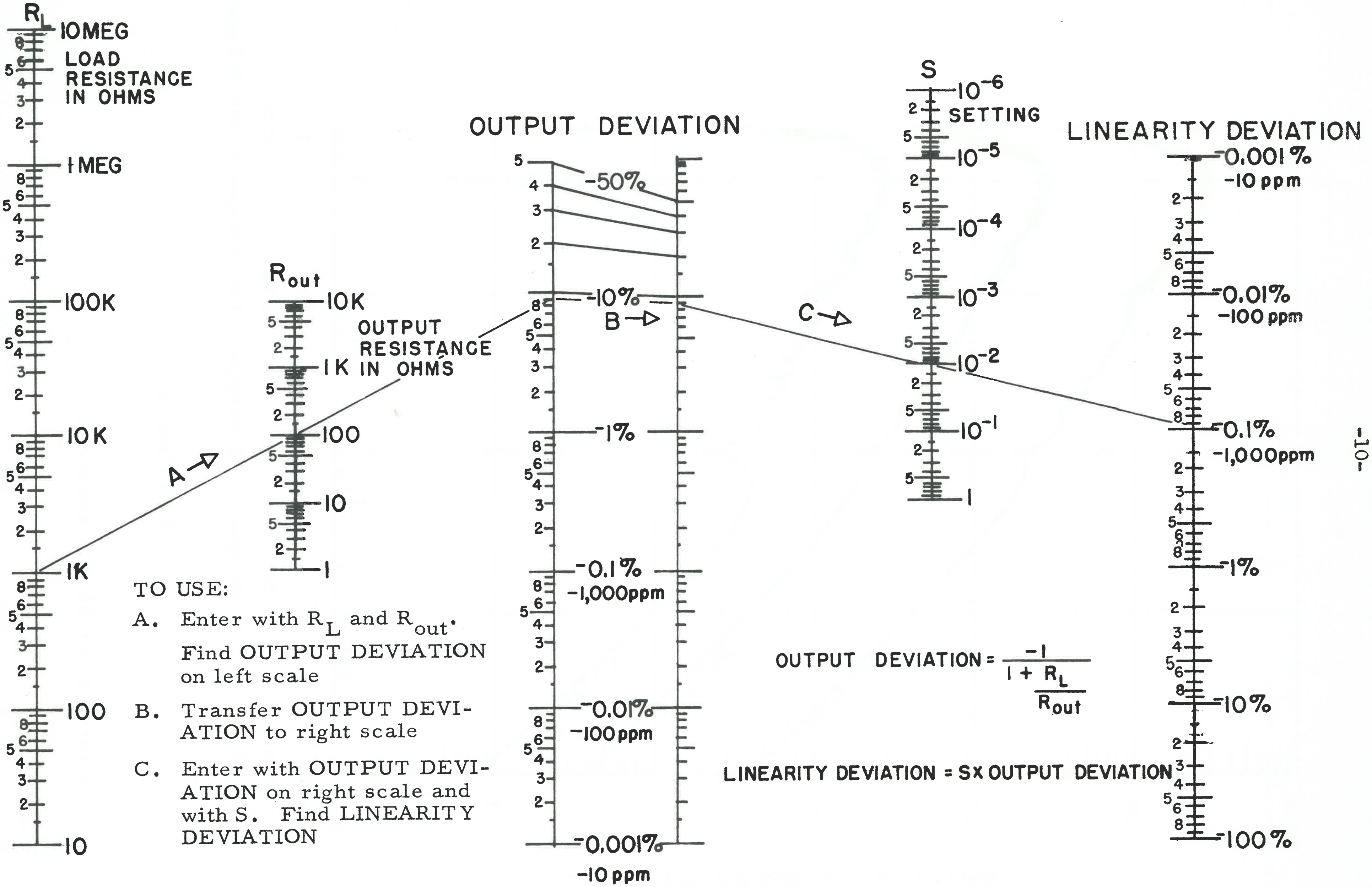


Figure 1d for DP-211 and DV-211



TO USE:

A. Enter with R_L and R_{out}. Find OUTPUT DEVIATION on left scale

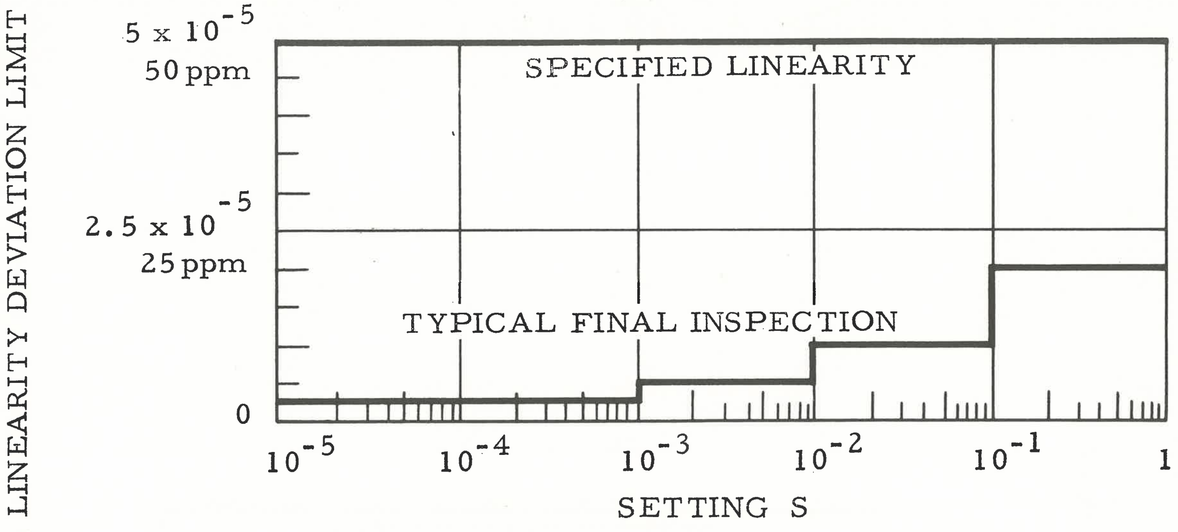
B. Transfer OUTPUT DEVIATION to right scale

C. Enter with OUTPUT DEVIATION on right scale and with S. Find LINEARITY DEVIATION

$$\text{OUTPUT DEVIATION} = \frac{-1}{1 + \frac{R_L}{R_{out}}}$$

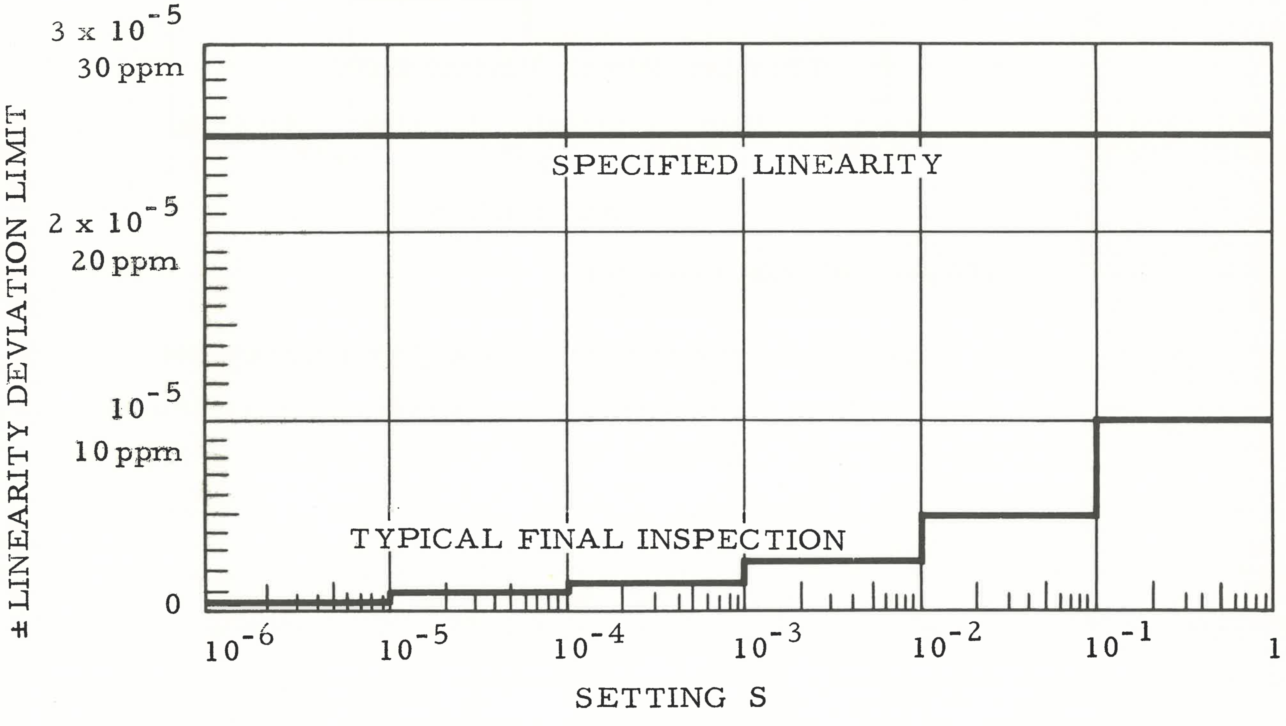
$$\text{LINEARITY DEVIATION} = S \times \text{OUTPUT DEVIATION}$$

Figure 2 NOMOGRAM FOR OUTPUT DEVIATION AND LINEARITY DEVIATION DUE TO OUTPUT LOADING



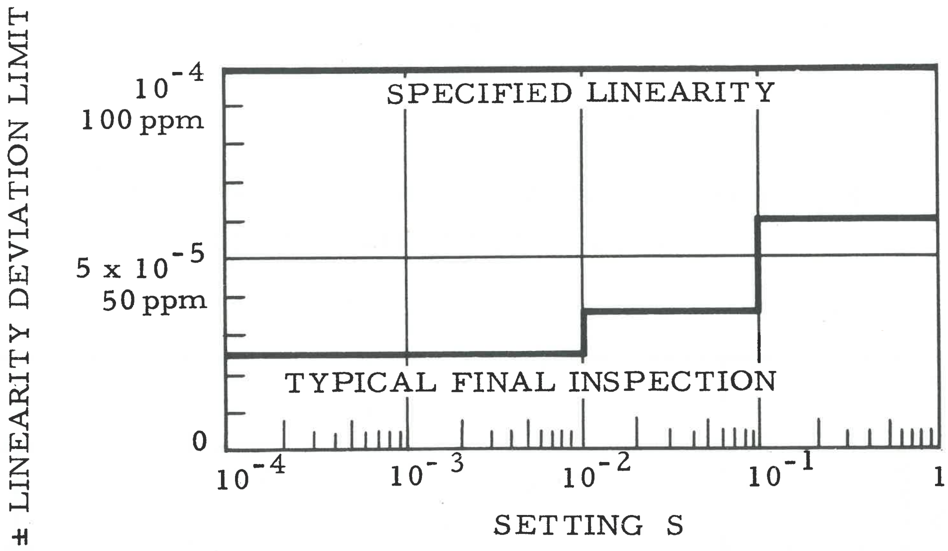
(10 ppm per dial division)

Figure 3a MAXIMUM LINEARITY DEVIATION (NO LOAD) for DP-311, DP-411, DV-311 and DV-411



(1 ppm per dial division)

Figure 3b MAXIMUM LINEARITY DEVIATION (NO LOAD) for RV-622 and RV-632



(100 ppm per dial division)

Figure 3c MAXIMUM LINEARITY DEVIATION (NO LOAD) for DP-211, DV-211 and DP-213

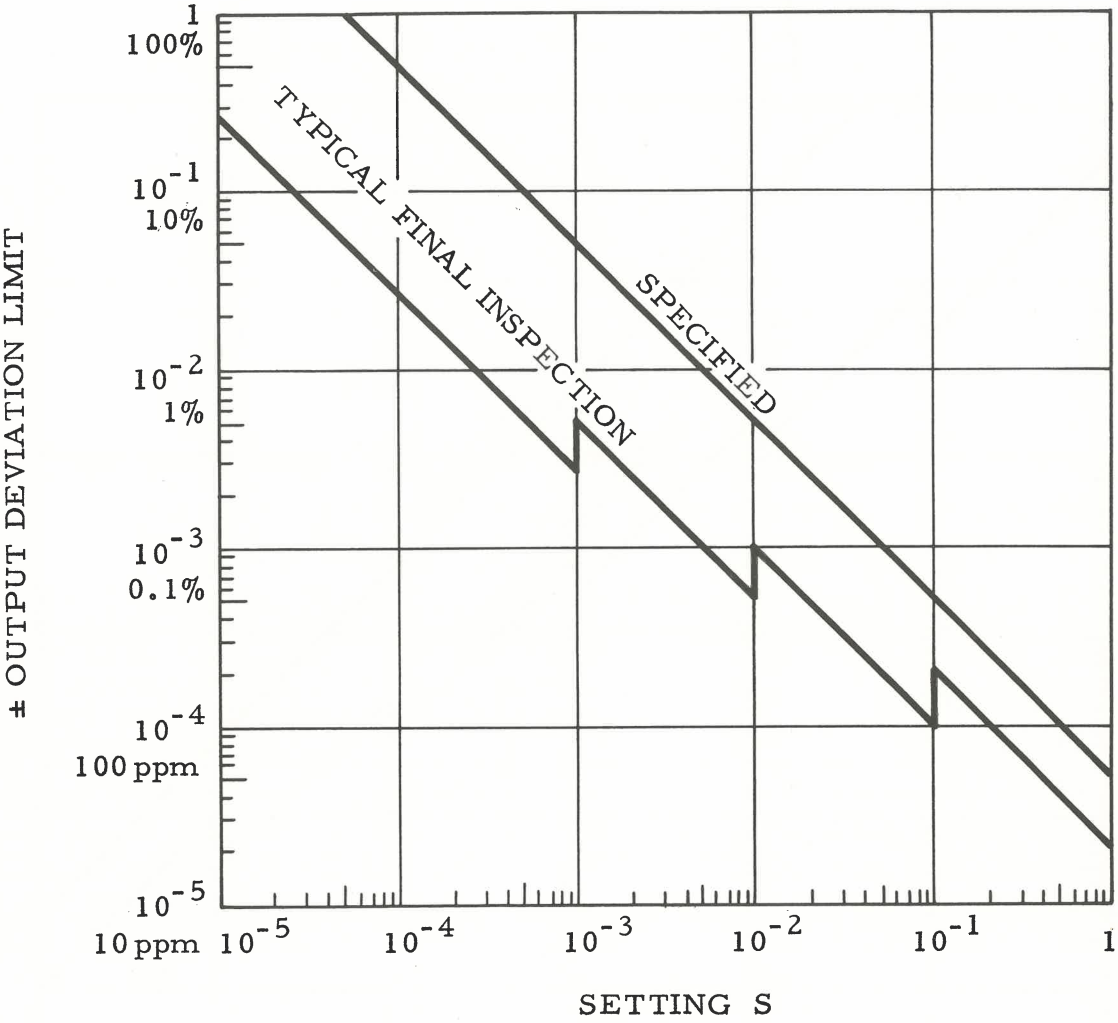


Figure 4a MAXIMUM OUTPUT DEVIATION (NO LOAD) for DP-311, DP-411, DV-311 and DV-411

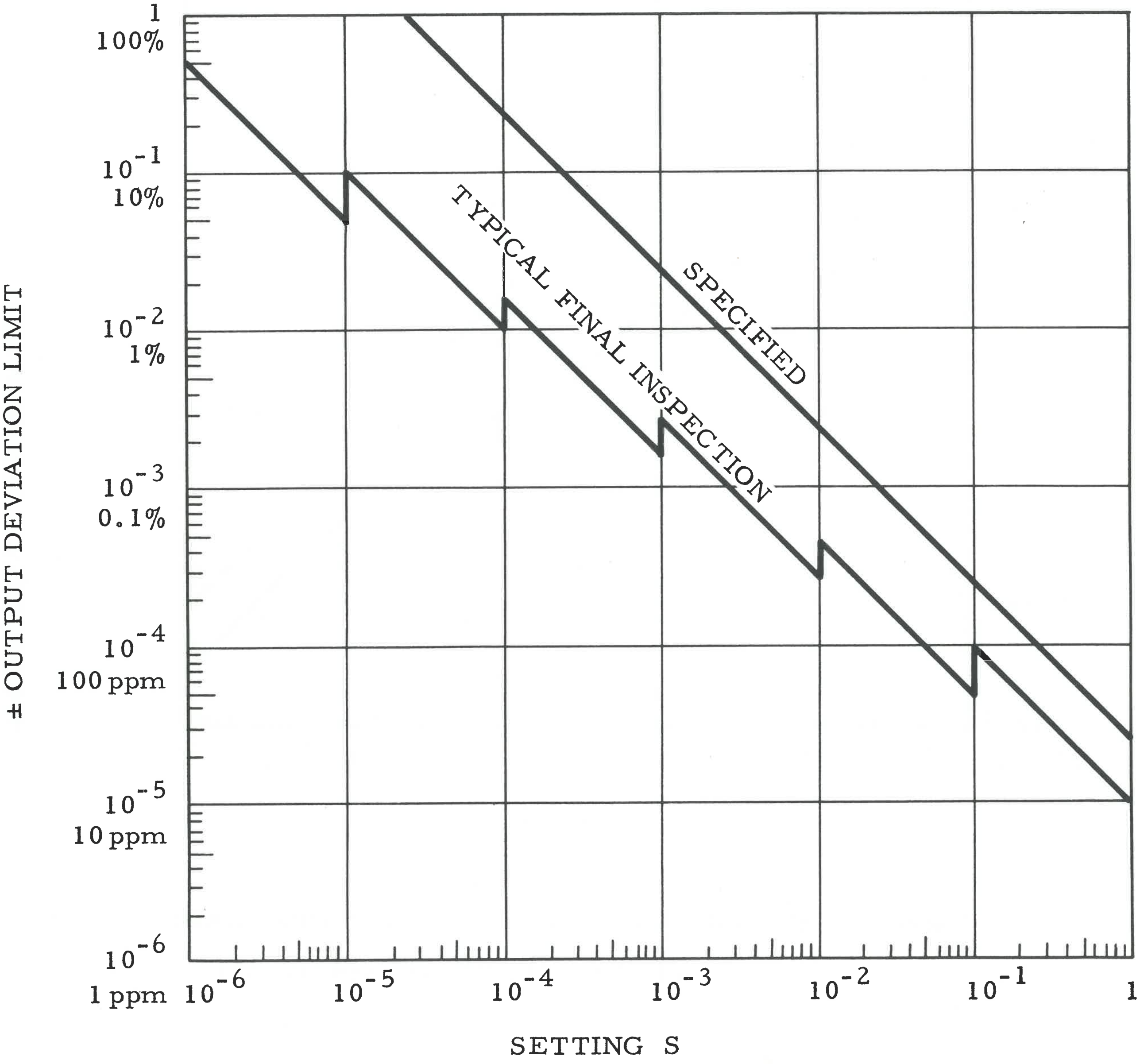


Figure 4b MAXIMUM OUTPUT DEVIATION (NO LOAD) for RV-622 and RV-632

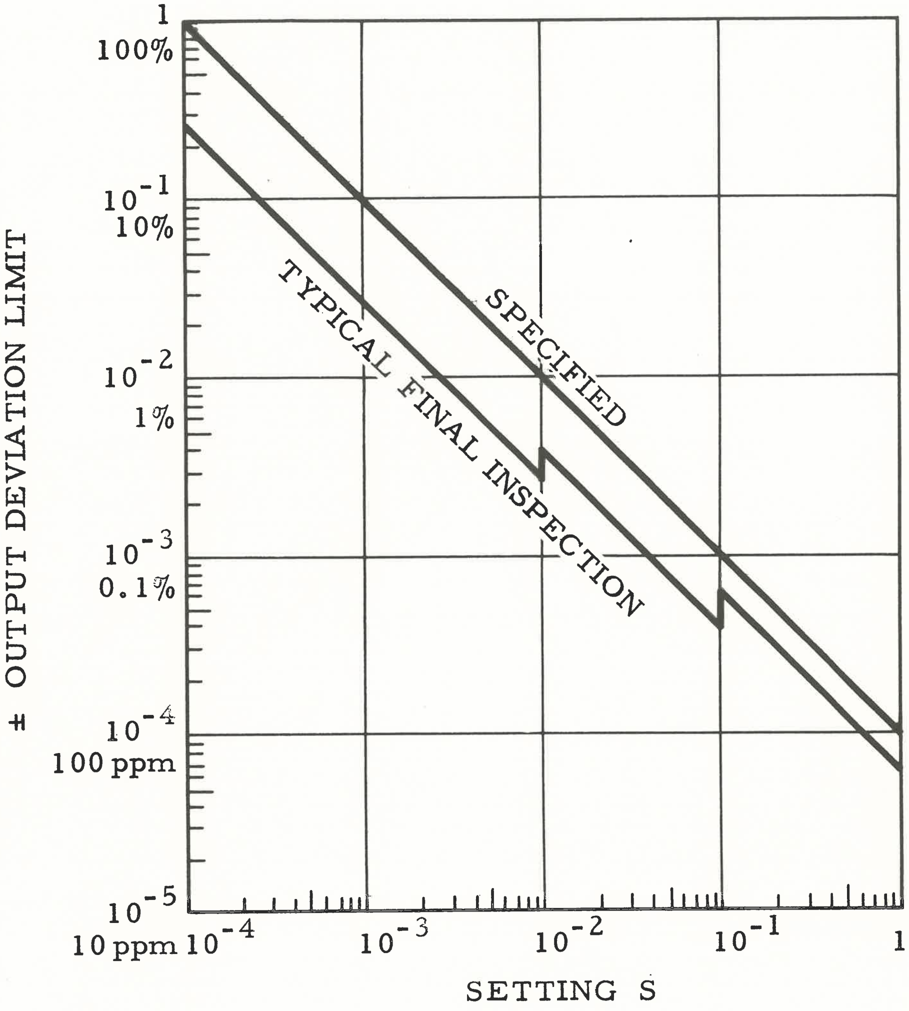


Figure 4c MAXIMUM OUTPUT DEVIATION (NO LOAD) for DP-211, DV-211 and DP-213